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Dynamics of steady-state gravity-driven inviscid flow in an open system

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Abstract

Various factors can be responsible for the flow of incompressible fluid under gravity. Torricelli's theorem gives the relationship between the efflux velocity of an incompressible, gravity-driven flow from an orifice and the height of liquid above it. The concept of the original derivation of Torricelli’s theorem is limited in application because of certain inherent assumptions in the method of derivation. An alternate method of derivation is the use of Bernoulli’s principle. However, its result tends towards Torricelli’s flow only with some assumptions. In this study, an inherent assumption was incorporated into the conventional method of derivation to obtain an amended Torricelli’s equation. This study also considers a more general approach of derivation with Bernoulli’s principle, which tends to eliminate some of the limitations. The method involves the theoretical construction of gravity-driven flow from the bottom of a reservoir that is opened to atmospheric pressure. Bernoulli’s equation, with the continuity equation, is applied to gravity-driven open flow. The derived equations are used to analyze the prerequisite conditions for vertical flow in an open system and the variables that affect the flow rate. It is assumed that the flow is steady, inviscid, and has one inlet port and one exit port. Findings show that the surface area ratio of discharge to upstream, which was neglected in the convectional Torricelli velocity, can influence the velocity significantly. The study shows that a high surface area ratio can be used to augment the velocity of established flow for a decreased flow height.

Keywords:

Bernoulli’s principle Energy conservation Fluid flow Gravity-driven flow Torricelli’s law Steady state flow.